Economic Modelling 51 (2015) 315–327

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

A penalty function approach to occasionally binding credit constraints☆

Michał Brzoza-Brzezina, Marcin Kolasa *, Krzysztof Makarski

Narodowy Bank Polski, ul. Świetokrzyska 11/21, 00-919 Warszawa, Poland
Warsaw School of Economics, Al. Niepodległości 162, 02-554 Warszawa, Poland

ARTICLE INFO

Article history:
Accepted 31 July 2015
Available online 8 September 2015

Keywords:
Financial frictions
DSGE models
Occasionally binding constraints
penalty function

ABSTRACT

Empirical evidence suggests that contractionary monetary and macroprudential policies have stronger effects than expansionary ones. We introduce this feature into a structural DSGE model with financial frictions. The asymmetry results from the assumption of occasionally binding credit constraints which we introduce via a penalty function. Our simulations show that a large loan-to-value ratio (our macroprudential tool) tightening can have a much stronger impact on the economy than a loosening of the same size. In contrast, small policy innovations, whether expansionary or contractionary, have effects of almost equal magnitude. Our approach provides an interesting way of modeling asymmetric effects of financial frictions for policy purposes.

1. Introduction

After the eruption of the financial crisis, introducing financial frictions into macroeconomic models moved to the forefront of economic research. Such models were designed not only to help us understand what happened during the crisis, but foremost to design new policies that could prevent such developments in the future. To be more specific, the literature has focused on a number of issues, from explaining the role of financial shocks during the crisis (Brzoza-Brzezina and Makarski, 2011; Gerali et al., 2010; Iacoviello and Neri, 2010; Lombardo and McAdam, 2012), through analyzing optimal monetary policy in the presence of financial frictions (Carlstrom et al., 2010; De Fiore and Tristani, 2013; Kolasa and Lombardo, 2014), to the impact of macroprudential regulations on the economy (Aliaga-Díaz and Olivero, 2012; Angeloni and Faia, 2013; Meh and Moran, 2010).

From the current policy perspective, this last area of research seems most important. Several central banks have decided to start conducting macroprudential policies that are expected to prevent the buildup of large financial imbalances in the future (e.g. ESRB, 2014). Since these policies did not exist in the past, their impact on the economy cannot be measured using econometric models. As a result, structural dynamic stochastic general equilibrium (DSGE) models are an attractive tool to explore the transmission of these policies.

A substantial part of these models introduces financial frictions in the form of credit constraints. In this concept, that can be traced back to the seminal paper of Kiyotaki and Moore (1997), some agents (entrepreneurs or households) are limited in their borrowing capacity by the amount of collateral that they can provide to the lender. The constraint is usually assumed to be eternally binding, which facilitates the model solution as standard perturbation techniques can be applied. However, while conceptually and computationally attractive, the eternally binding constraint (EBC) setup suffers from major shortcomings.

First, as documented by Brzoza-Brzezina et al. (2013), the permanent nature of collateral constraints generates strong, short-lived and symmetric reactions of macroeconomic variables to shocks. This means in particular that the EBC modeling strategy does not allow to distinguish between "normal" and "stress" periods. In contrast, Hubrich and Tetlow (2015) show on empirical grounds that negative output effects of financial shocks are much more pronounced and long-lasting in times of high financial stress than in normal times. Kaufmann and Valderrama (2010) show that amplifying effects of credit shocks work in a highly nonlinear fashion. They identify periods during which loan shocks have only moderate effect on GDP and periods when they strongly amplify the cycle.

Second, eternally binding constraints seem to be also inconsistent with empirical evidence on business cycle features. Table 1 presents the skewness (i.e. the third standardized moment) for main variables related to the housing market. The reason for looking at this part of the economy is its important role in driving the business cycle and modeling financial frictions and macroprudential policy (see e.g. Iacoviello and Neri, 2010). It is clear that residential investment, housing stock, change in mortgage loans and house price inflation are all skewed

☆ This project was financed by the National Science Centre grant No. 2012/05/B/HS4/04158. The views expressed herein are those of the authors and not necessarily those of the Narodowy Bank Polski. We would like to thank Łukasz Drozd, Tom Holden, Matteo Iacoviello, Giovanni Lombardo, Jaromir Nosal for helpful discussions and three anonymous referees for useful suggestions to the previous drafts. This paper benefited also from comments received at the 18th CEF conference in Prague, 2012 WIEM in Warsaw, 8th Dynare conference in Zurich, 44th MMF conference in Dublin, 21st Annual Symposium of the SNDE in Milan, EcoMod2015 Conference in Boston, 2nd FMND in Paris and seminar at the Narodowy Bank Polski.

* Corresponding author at: Warsaw School of Economics, Al. Niepodległości 162, 02-554 Warszawa, Poland.

E-mail addresses: mbrzez@sgh.waw.pl (M. Brzoza-Brzezina), mkolas@sgh.waw.pl (M. Kolasa), kmakar@sgh.waw.pl (K. Makarski).

http://dx.doi.org/10.1016/j.econmod.2015.07.021
0264-9993/

Table 1
Skewness of main housing market variables.

Variable	Skewness
Real house price inflation	−1.17**
Housing investment	−0.48**
Housing stock	−0.50**
Real mortgage loans	−0.05
Real mortgage loans (growth rate)	−0.30*

Note: Real house prices reflect the CPI deflated Case-Schiller index (Source: Standard&Poors; 1q1987 - 3q2011). Housing investment is defined as real private residential investment (Source: BEA; 1q1950–4q2011). Housing stock stands for real private residential fixed assets (Source: BEA; 1950–2010). Real mortgage loans are CPI deflated home mortgages of households and non-profit organizations (Source: Board of Governors; 1q1952–3q2011). All variables are detrended with the Hodrick-Prescott filter.
* Denote significance at the 1% level.
** Denote significance at the 5% level.

downwards, i.e. left tail events are relatively more frequent. This suggests that the economy responds to shocks in a skewed fashion.

This evidence suggests that assuming eternally binding credit constraints can generate misleading conclusions about the impact of financial shocks and working of macroprudential policy. For instance, one can expect that under occasionally binding credit constraints macroprudential policy that uses the loan-to-value ratio as instrument will be more effective in a tightening than in a loosening cycle. A model with EBC will not reflect this feature and, thus can mislead policymakers.

In this paper we explore the introduction of occasionally binding constraints (OBC) into models with financial frictions and macroprudential policy. The idea is not new, see e.g. Christiano and Fisher (2000), Mendoza (2010) or Brunnermeier and Sannikov (2014). However, given their highly non-linear nature, models featuring OBC should ideally be solved with global methods. Unfortunately, these can be applied only to relatively small models with a limited number of state variables. In spite of the progress achieved in the area of global solution techniques in recent years, such methods are still out of range for models of the size used for practical policymaking, i.e. featuring a number of real and nominal rigidities. For instance, Fernández-Villaverde et al. (2015) use collocation methods to solve a New Keynesian model at the zero lower bound. However, their model features only five state variables. Adding standard features of models currently used at central banks, like endogenous capital, habit formation, wage rigidity, interest rate inertia or indexation (Christiano et al., 2005; Smets and Wouters, 2003) would more than triple the number of state variables, making a global solution impossible to obtain in reasonable time. At the same time, adding these frictions seems indispensable when the models are to be applied for instance for analyzing business cycle consequences of monetary and macroprudential policies. For such models, local solution methods are still the only feasible option.

For these reasons, we thoroughly investigate a potentially attractive shortcut to approximate occasionally binding constraints that has been introduced by Luenberger (1973) and Judd (1998), and more recently advocated by De Wind (2008), i.e. the so-called barrier or penalty function method. This approach essentially consists in converting inequality constraints into equality constraints, making the use of standard perturbation techniques possible. The method has been applied to a range of medium-sized macroeconomic models e.g. by Rotemberg and Woodford (1999) and Kim et al. (2010).[1] To this end, we construct a DSGE model with a standard set of rigidities and collateral constraints in the spirit of Iacoviello (2005), except that the latter are introduced in the form of a smooth penalty function. We parameterize the model in such a way that the constraint does not play an important role close to the steady state, but becomes binding when the economy is hit by sufficiently large negative shocks. Next, we investigate the main features of the model both under perfect foresight and in a stochastic setting using its local approximations of various orders.

Our main findings are as follows. First, the introduction of occasionally binding constraints via the penalty function approach allows to generate asymmetric and non-linear reactions of the economy to macroprudential policy and (to a lesser degree) monetary policy shocks. We show for instance that with OBC a macroprudential tightening has stronger effects on the economy than a loosening. Second, this feature can be also reproduced for local approximations, though only for orders higher than two. Third, and less positive, stochastic simulations for the 2nd, 3rd and 4th order approximations either fail to render the appropriate shape of the penalty function or suffer from serious stability problems that make them inapplicable in practice. This finding stands in contrast to De Wind (2008), who shows that for a simple model with a penalty function, higher order perturbation can be a feasible solution method. We show that this result does not translate into more sophisticated models. It should be noted that, while our focus is on credit constraints, the above stated conclusions regarding the application of penalty functions are also valid for other nonlinear economic problems, like downward wage rigidity or non-negativity of investment.

All in all, the penalty function approach can be considered an attractive way of introducing financial frictions into deterministic models like GEM (Tchakarov et al., 2004), QUEST (Ratto et al., 2009; Roeger and in't Veld, 2004) or EAGLE (Gomes et al., 2012). However, a fully fledged application in a realistic stochastic framework seems out of range.

The rest of the paper is structured as follows. In Sections 2 and 3 we present the model and its calibration. Section 4 uses deterministic simulations to present the model's features. In section 5 we investigate the performance of local approximations and their usefulness in generating stochastic simulations. Section 6 concludes.

2. Model

We consider a closed economy DSGE model in the spirit of Iacoviello (2005), where some agents face collateral constraints on their borrowing. In this section we first sketch out the structure of the model and then present two alternative specifications of the credit constraint, i.e. the EBC and OBC variants.

2.1. Households

There are two types of households indexed by ι on a unit interval: patient of measure ω_P and impatient of measure $\omega_I = 1 - \omega_P$.[2]

2.1.1. Patient households

In each period, patient households decide on their consumption of goods $c_{P,t}$ and housing services $\chi_{P,t}$, labor supply $n_{P,t}$, capital stock k_t and savings deposits in the banking sector D_t.[3] There are no financial frictions on the depositors' side and hence patient households can save at the policy (interbank) rate R_t. They are also assumed to own all firms and banks in the economy, which pay them dividends $\Pi_{P,t}$.

[1] An alternative approach that has been recently proposed to tackle occasionally binding constraints is the piecewise-linear perturbation method of Guerrieri and Iacoviello (2015). This method is attractive because it can be easily applied to models with many state variables. However, in contrast to the penalty function method, it ignores the precautionary motives that are linked to the possibility of hitting the constraint. As a result, the piecewise-linear method cannot be used to evaluate welfare implications of alternative stabilization policies.

[2] We employ the following notational convention: all variables denoted with superscript P or I are expressed per patient or impatient household, respectively, while all other variables are expressed per all households. For example, k_t denotes per capita capital and since only patient households own capital, capital per patient households is equal to $k_{P,t} = k_t/\omega_P$.

[3] We calibrate the model so that patient households save and never borrow. Therefore, to simplify notation, we eliminate credit (which they would not take anyway) from their budget constraint. Similarly, we eliminate deposits from impatient households' budget constraint (6).